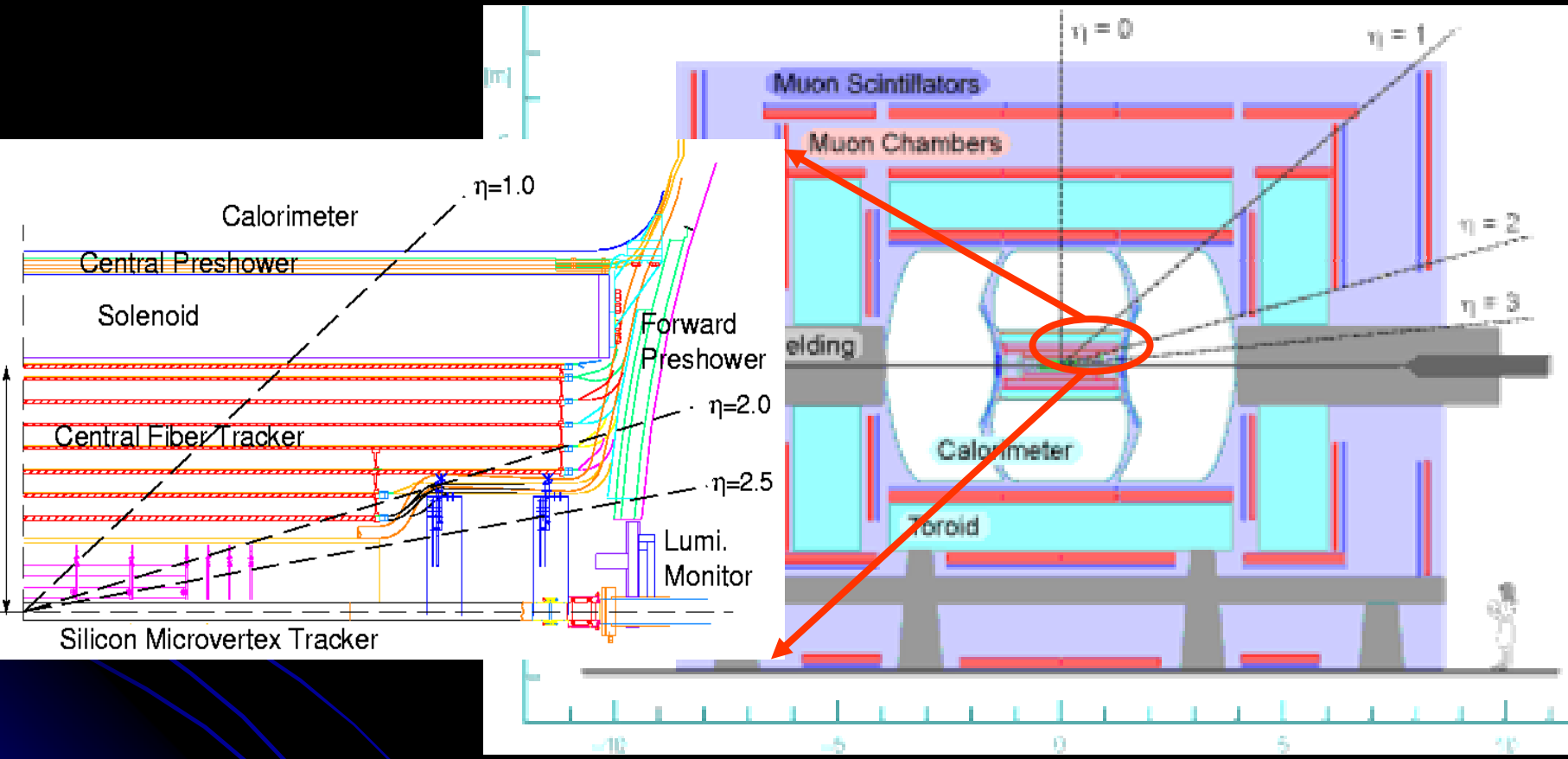
DØ Layer 0 – innermost layer of Silicon Microstrip Tracker

- Existing DØ detector
- Motivations
- Design
- Performance
- Conclusions

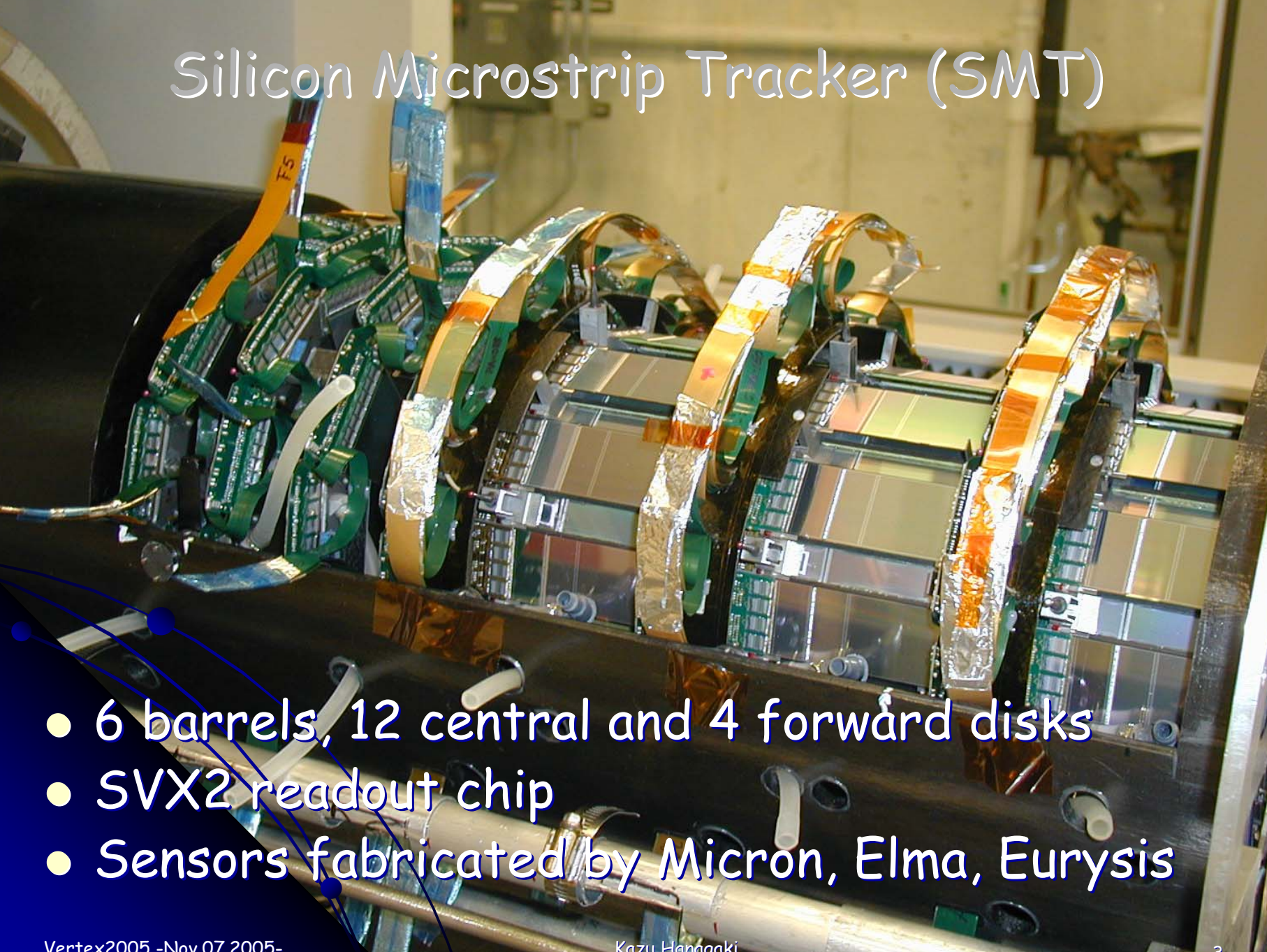
Kazu Hanagaki / Fermilab

The DØ Detector



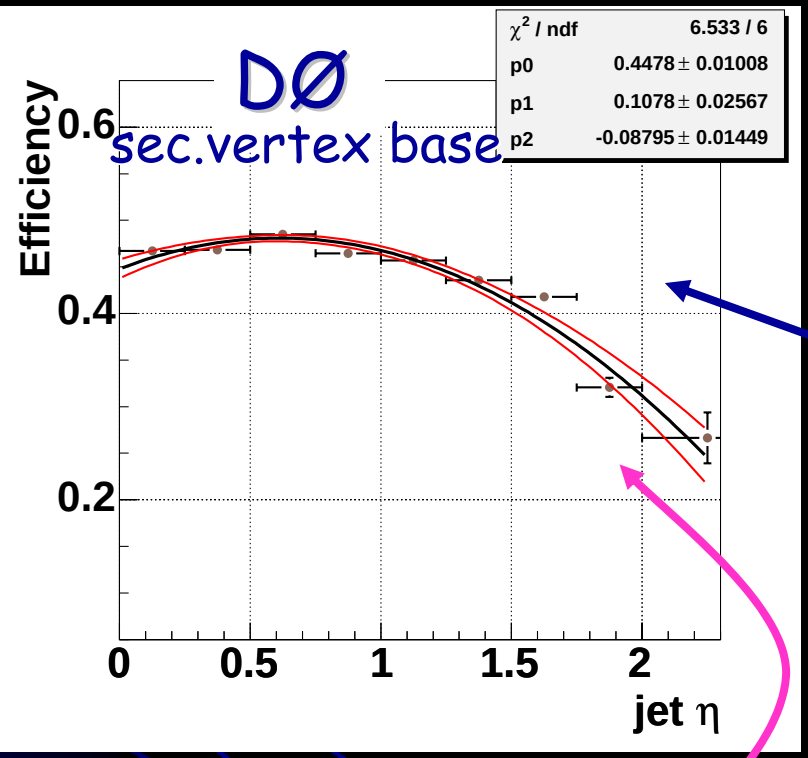
- Compact detector (tracker)
  - Large acceptance

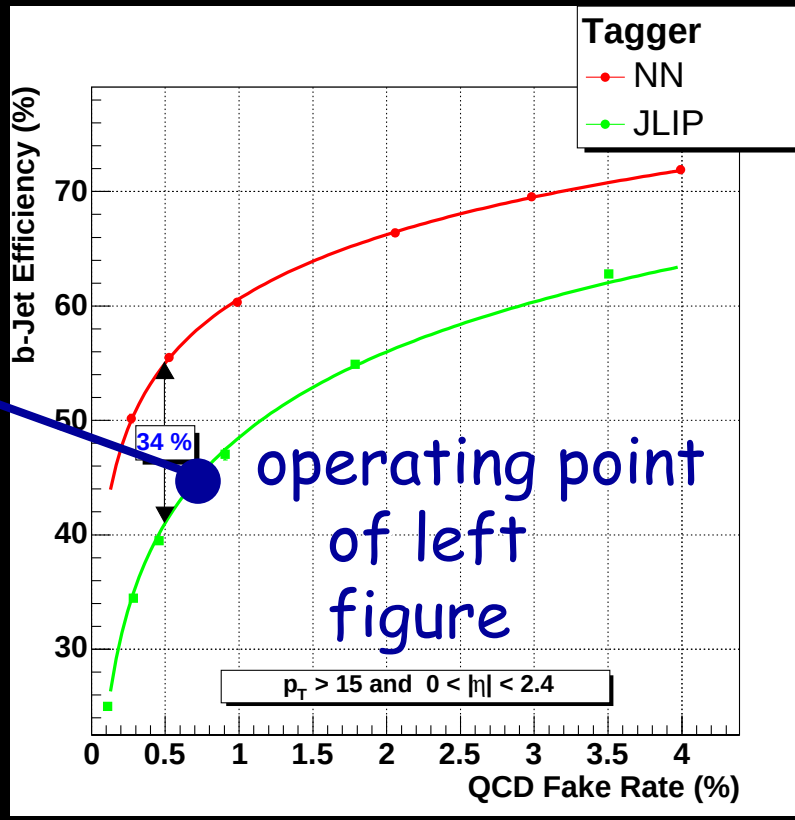
Silicon Microstrip Tracker (SMT)



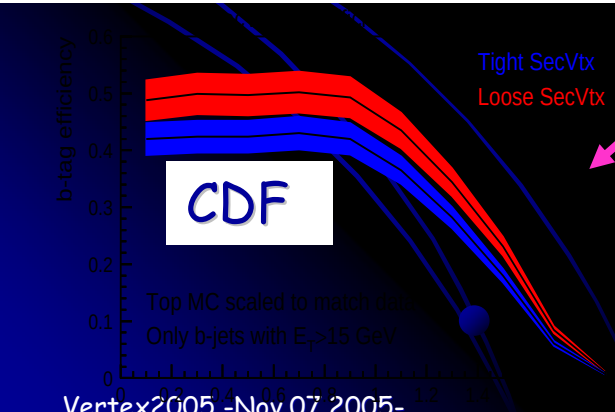
- 6 barrels, 12 central and 4 forward disks
- SVX2 readout chip
- Sensors fabricated by Micron, Elma, Eurysis

b-tag Performance





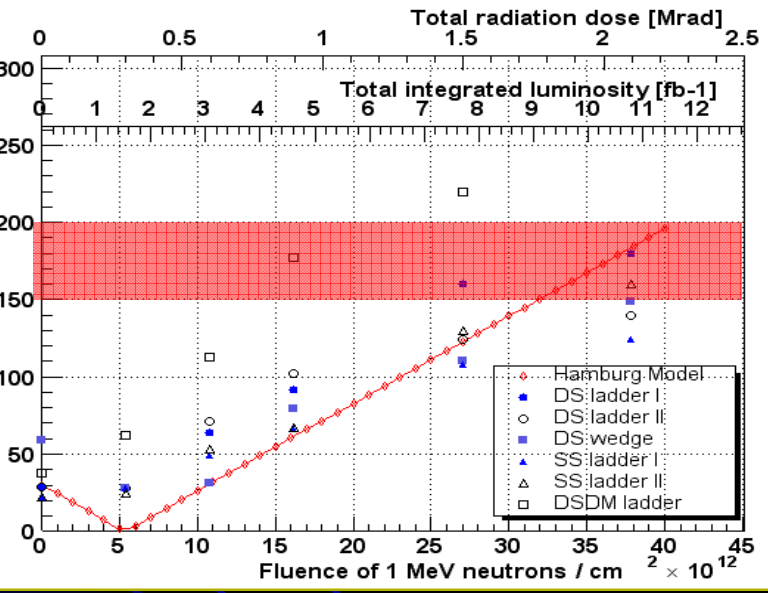
similar algorithm with similar fake



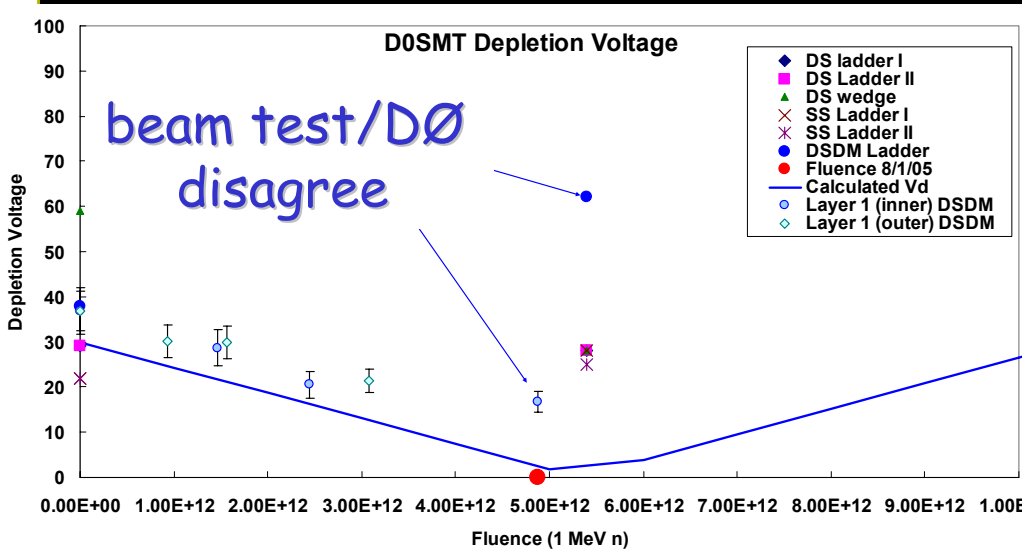
- Large acceptance as advertised

Motivations – radiation damage

Booster beam test results



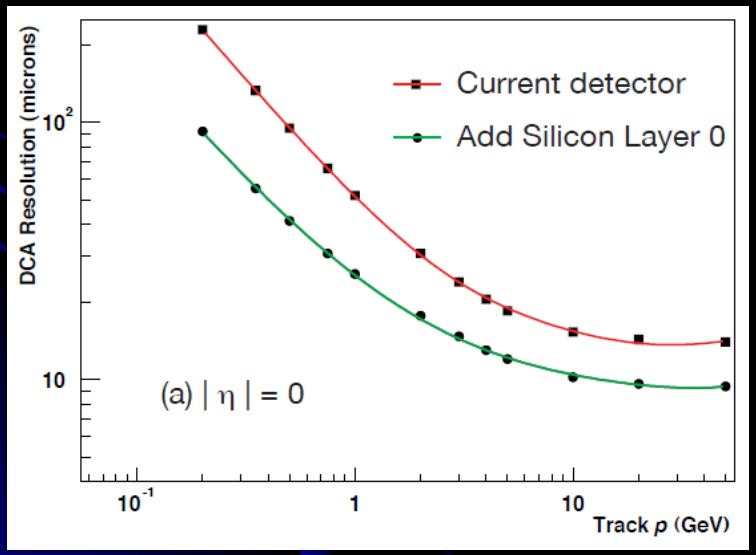
new result using the existing detector at DØ

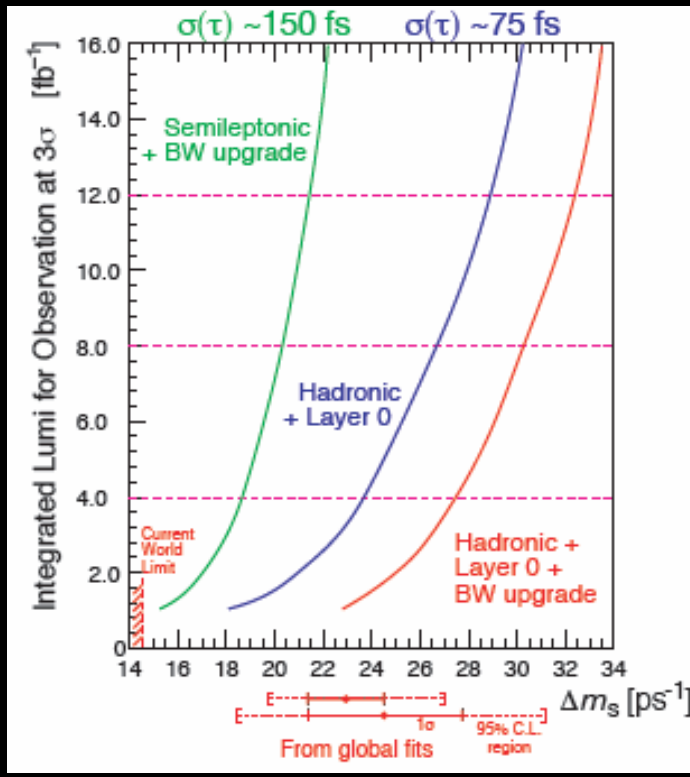


- Originally proposed to extend the lifetime of SMT (based on the booster test results)

Motivations – better resolution

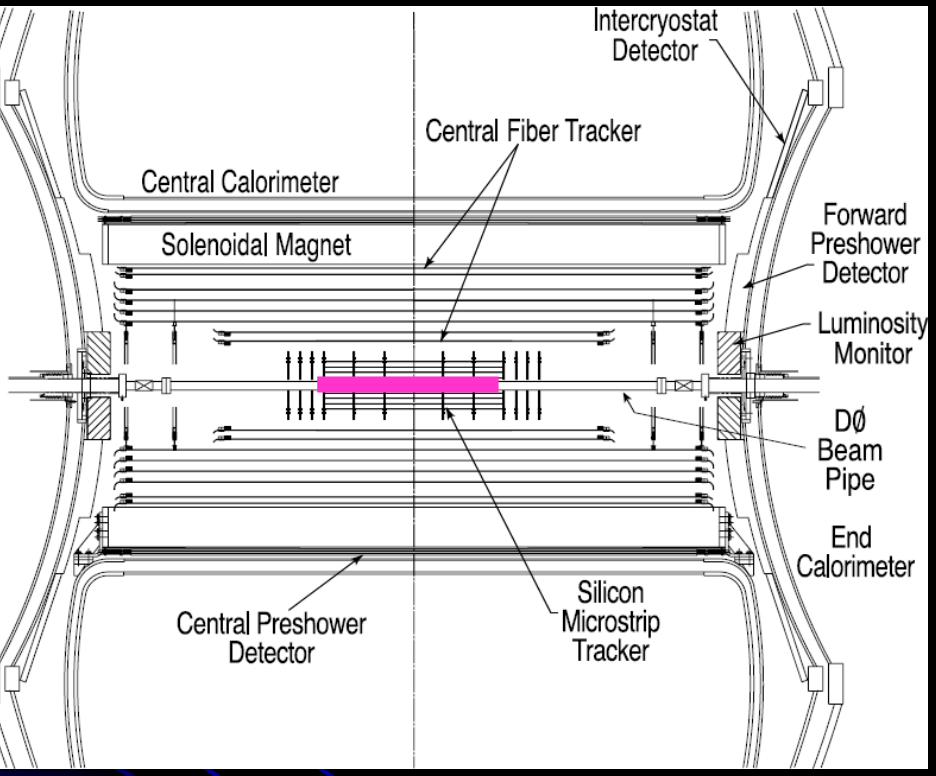
- r@L1 = 2.7 cm → r@L0 = 1.6 cm : better impact parameter resolution
- More redundancy in pattern recognition for higher luminosity

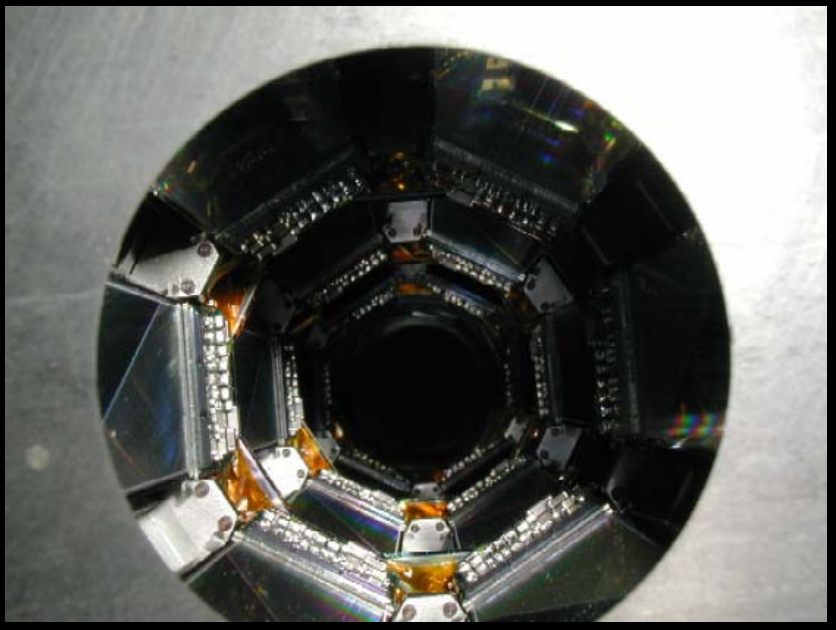


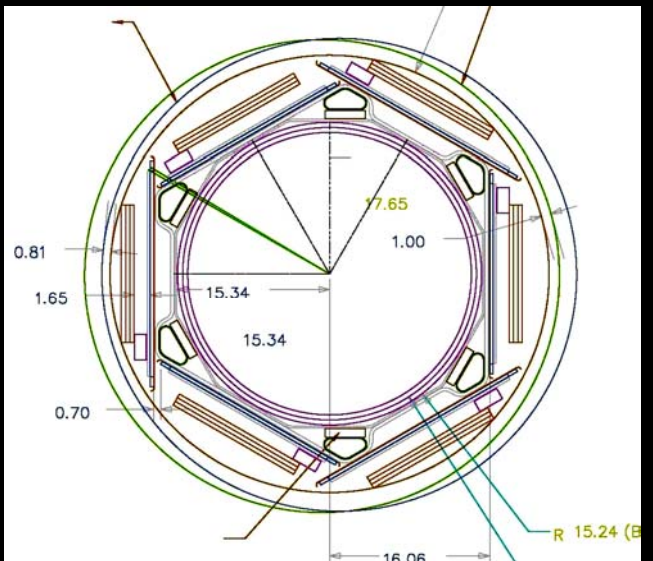


Design

Where does L0 go?







- Clearance
  - outer radius ~23mm
  - inner radius ~15mm

➔ very tight!

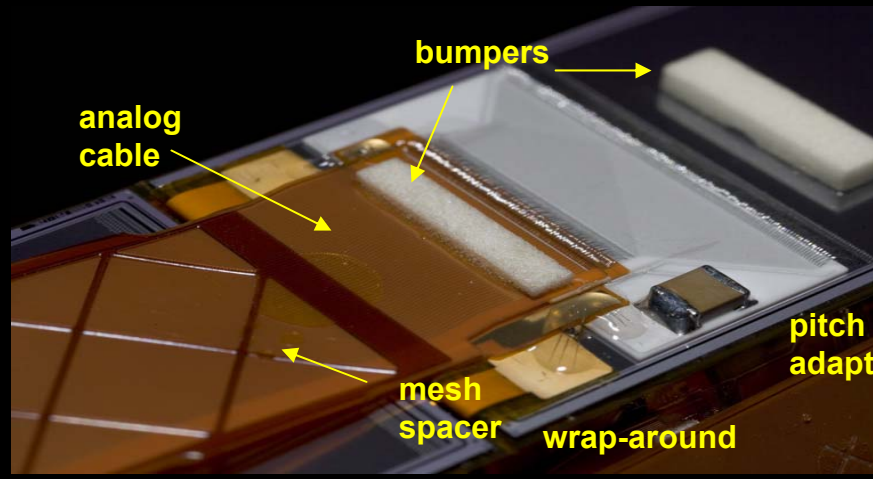
Overview

- Super tight space constraint!
  - readout chip outside the fiducial
    - cooling not enough
    - low mass
    - application of carbon fiber (CF) support structure as direct support of sensor
    - analog signal has to be transmit from sensor to readout chip

- Uses R&D and people invested to Run 2b which was cancelled at September 2003
- Goal: S/N > 10 after irradiation

Components

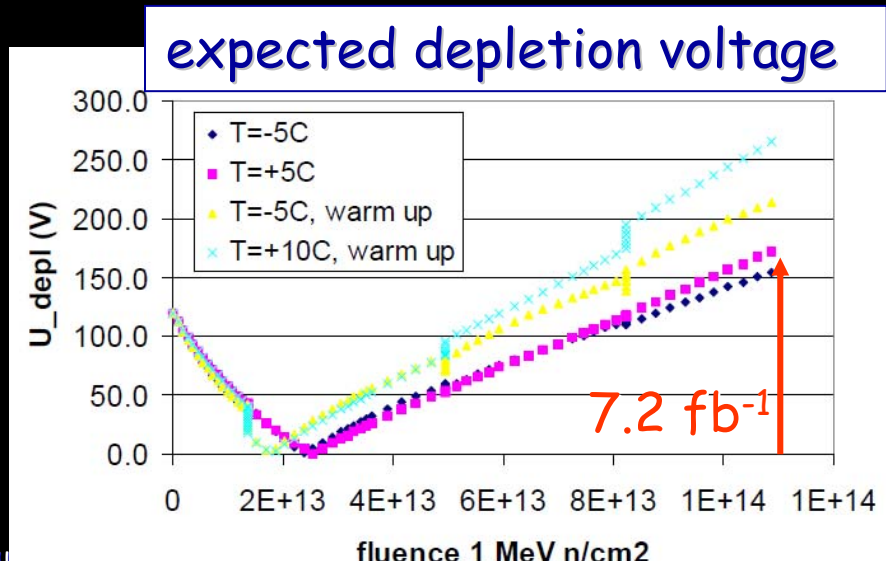
- 48 modules
  - sensor, x2 analog cable, x2 SVX4 on BeO hybrid
    - 256 channel per module
- Readout chain
  - digital jumper cable
  - junction card: impedance matching
  - twisted pair cable
  - adaptor card
    - SVX4 voltage regulation
    - differential (SVX4) → single ended (existing system)
    - regenerate clock
- Carbon fiber support
  - attach to existing detector



Sensor

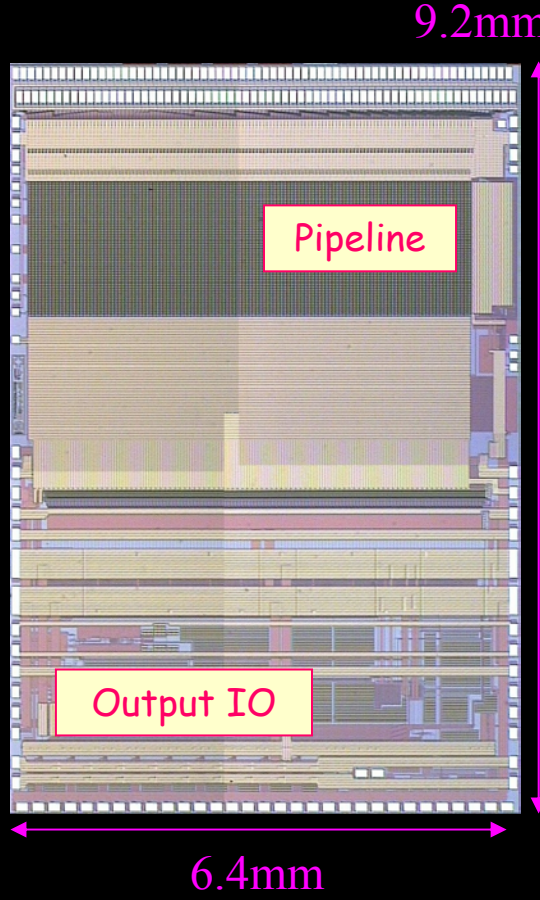
- Hamamatsu; AC-coupled, single-sided single-metal p^+ on n-bulk
  - sustain high bias voltage (500V) for rad-hard
  - beam test did not show any abnormal behavior
    - no junction break down up to 700V
    - depletion voltage as expected
- 71, 81 μm strip pitch w/ intermediate strip
  - #readout strips = 256
- Length: 7 or 12 cm

expected depletion voltage



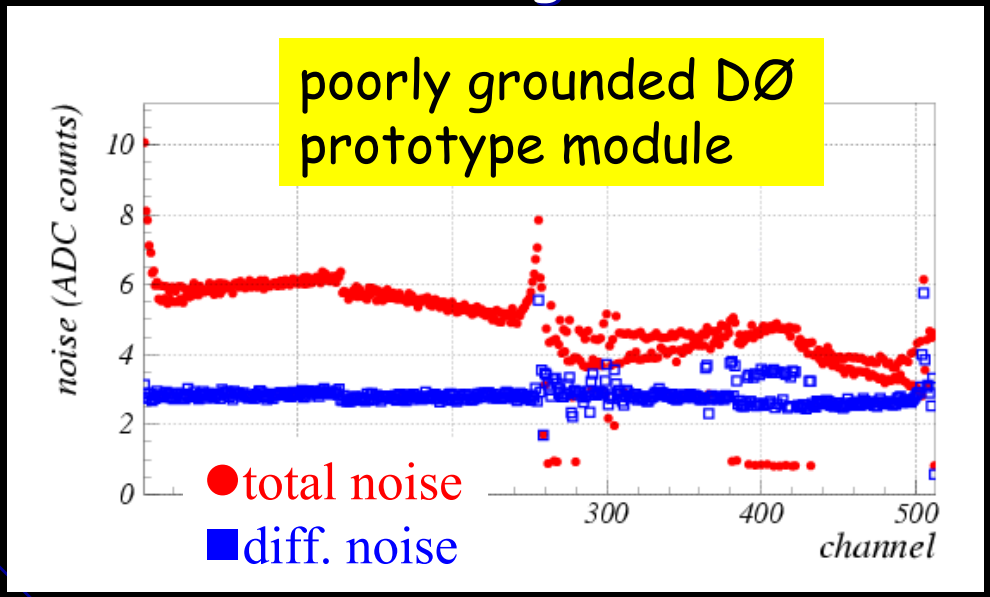
SVX4 Chip

- DØ and CDF (Fermilab and LBL) developed new readout chip
  - Successor of SVX2 and SVX3 chip
  - 0.25 μm technology, rad-hard
  - 128 inputs and 46+1 pipeline cells
  - 8-bit ADC with sparsification
  - 53 MHz readout, 106 MHz digitization
  - Programmable test pattern for calibrations, ADC ramp, preamp bandwidth
  - Pinhole clamping
  - Real time pedestal subtraction (RTPS)
  - 2.5 V, power measured to 0.3 W/chip



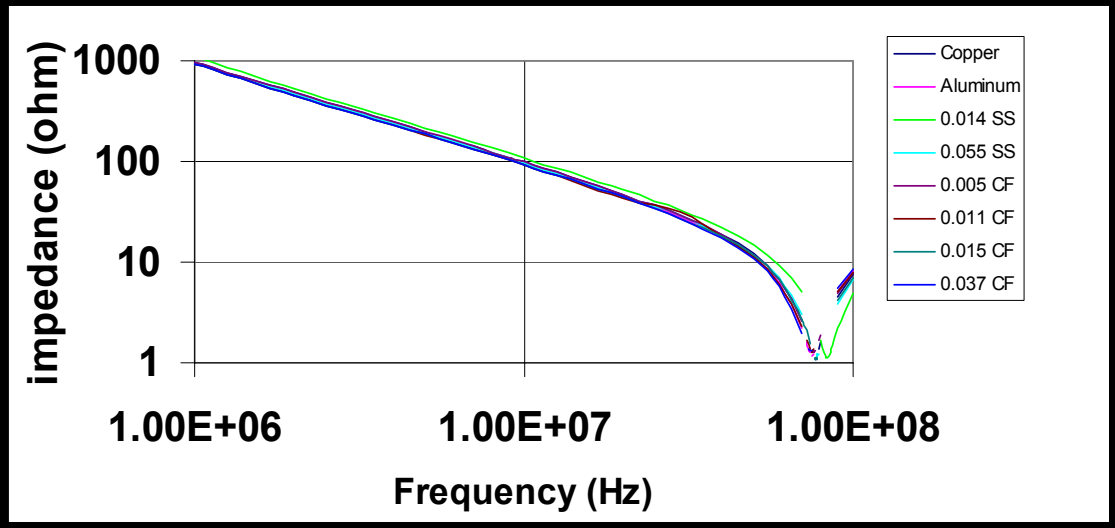
The Big Challenge – Noise

- The most difficult challenge (in terms of electronics) in LO is to reduce noise
  - Analog cable works as a "good" antenna

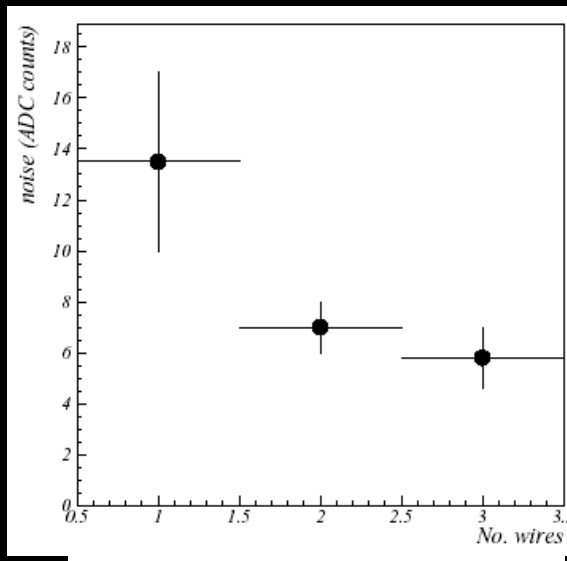


- With poor grounding scheme, the noise can be high as ADC overflow (255 ADC counts; 1MIP ~ 30 ADC counts)

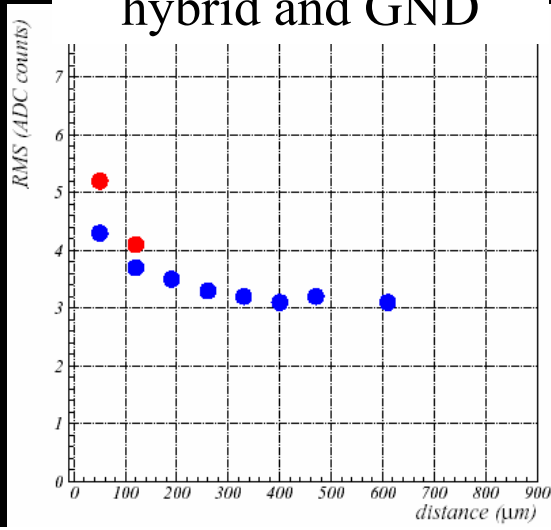
Grounding



- Carbon fiber is a good conductor
  - must be grounded
- Low inductance GND connection crucial
- Space between analog cable and carbon fiber support has to be maintained to avoid pickup

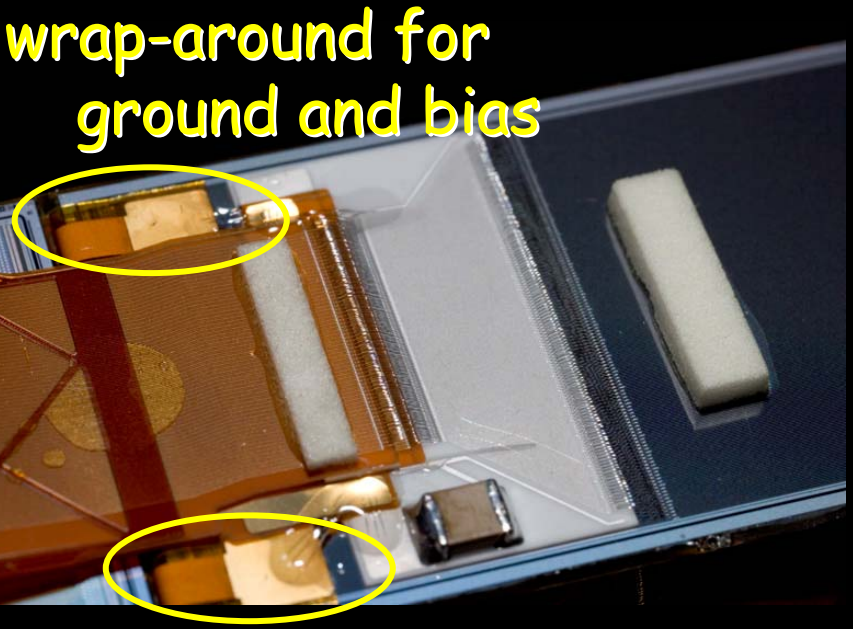


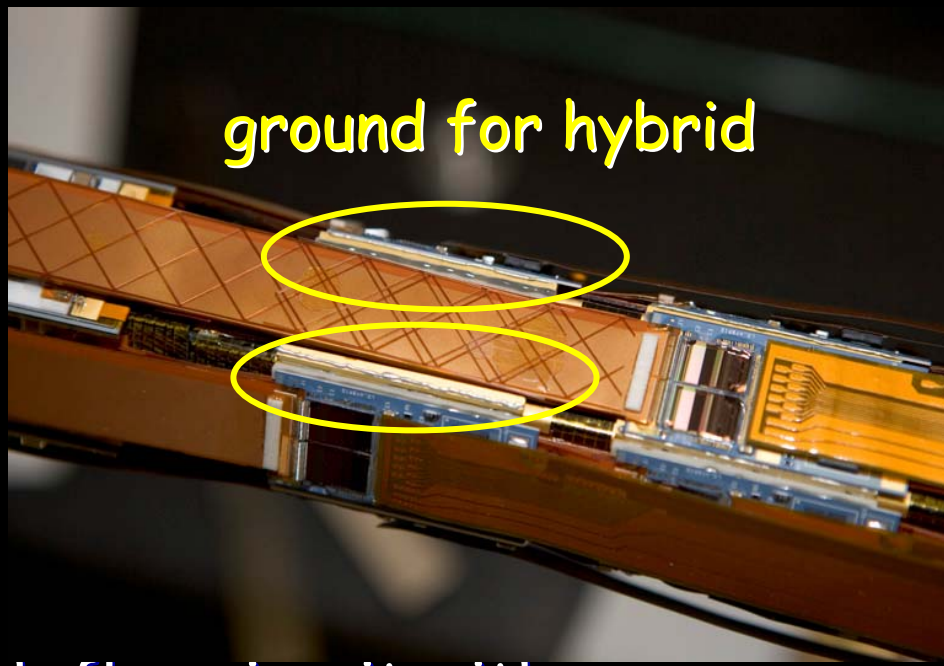
#wires between hybrid and GND



distance between analog cable and support

Some Tricks



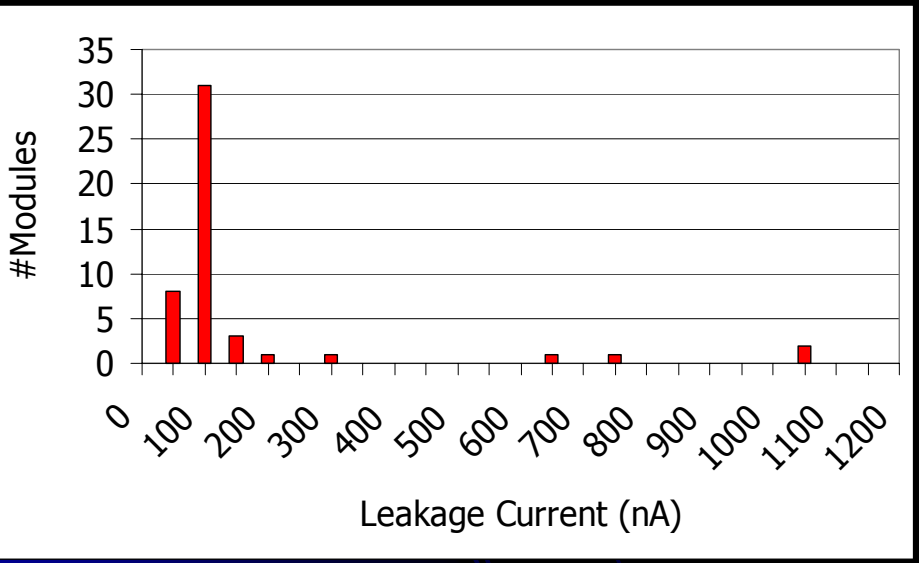


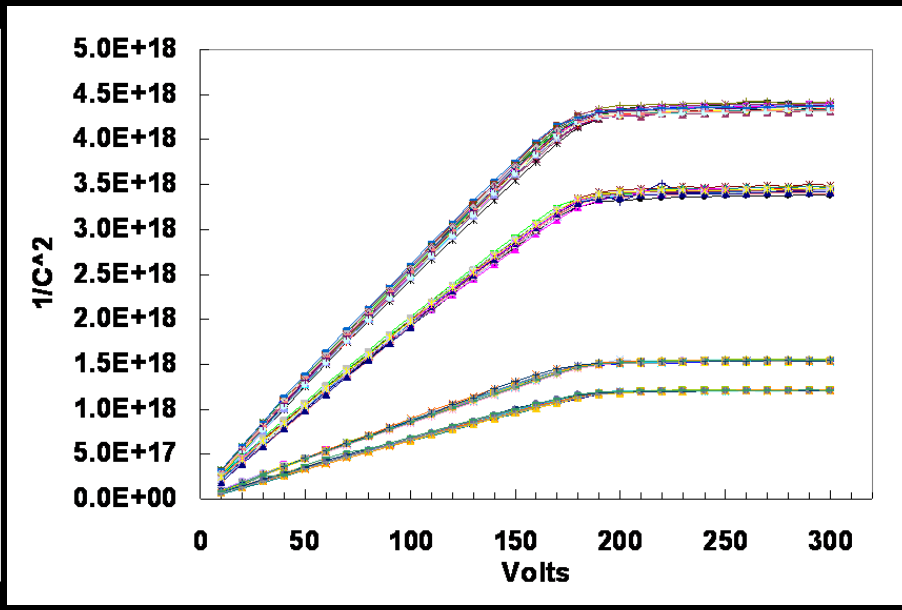
- Carbon fiber cocured with flex circuit with copper trace to achieve better contact
- Ground pads at backplane of hybrid
- Wrap-around to connect sensor GND to support (as well as bias voltage to backplane)
- Mesh (to minimize capacitance) spacer between analog cables

Performance

Sensors

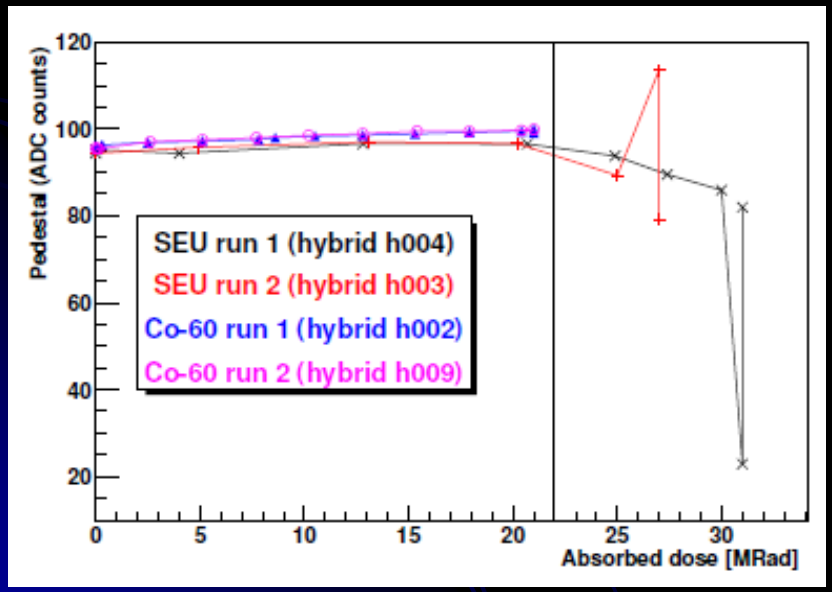
- Ordered 120 sensors
  - only one bad (pin-hole) channel out of 120 x 256 = 30720 channels ! (spec. 1%)
  - very small leakage current
  - depletion voltage almost identical for all sensors

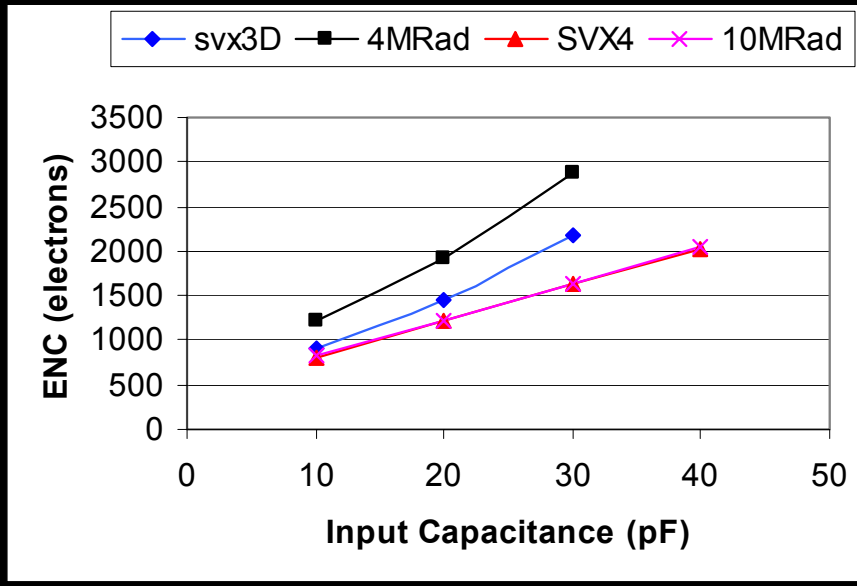




SVX4 Chip

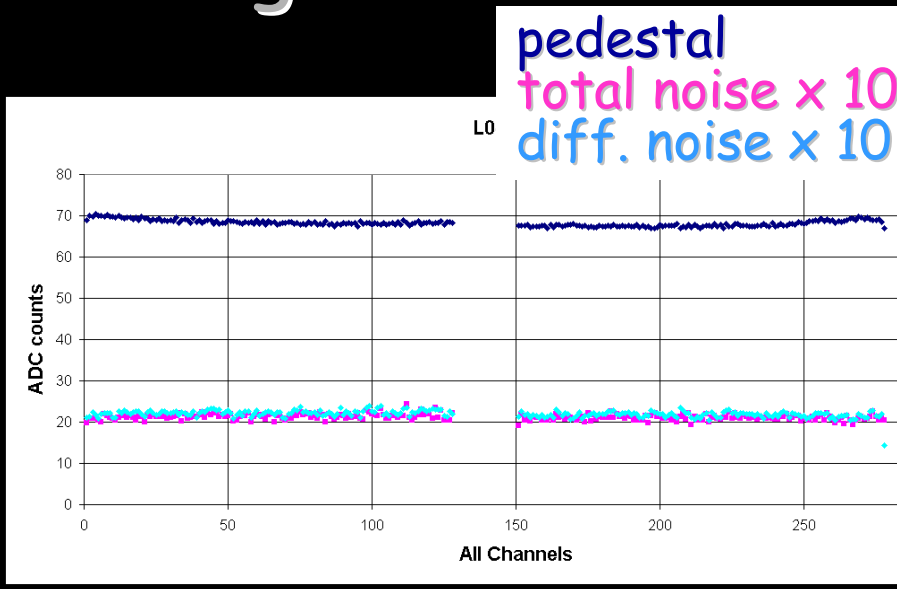
- Noise
  - For fixed rise time (69ns): ENC ≅ 300 + 41C (2025e⁻ @40pF)
- Radiation hardness
  - No degradation up to at least ~20Mrad

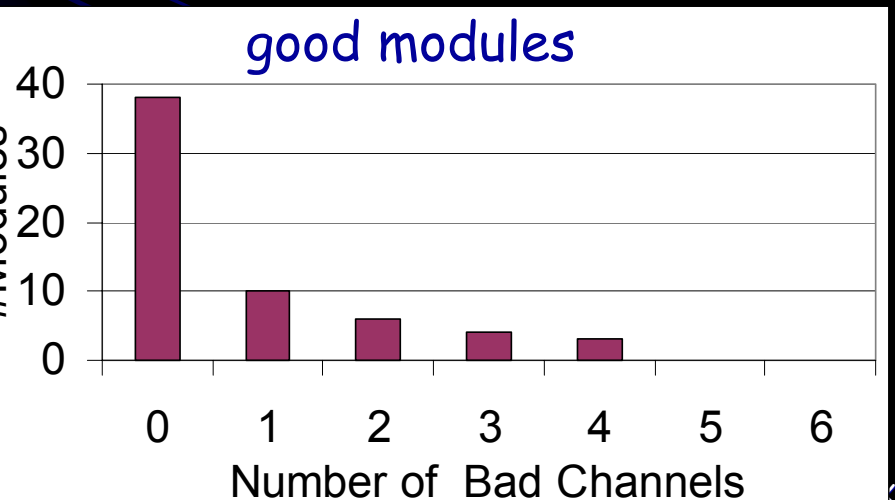




Module Testing

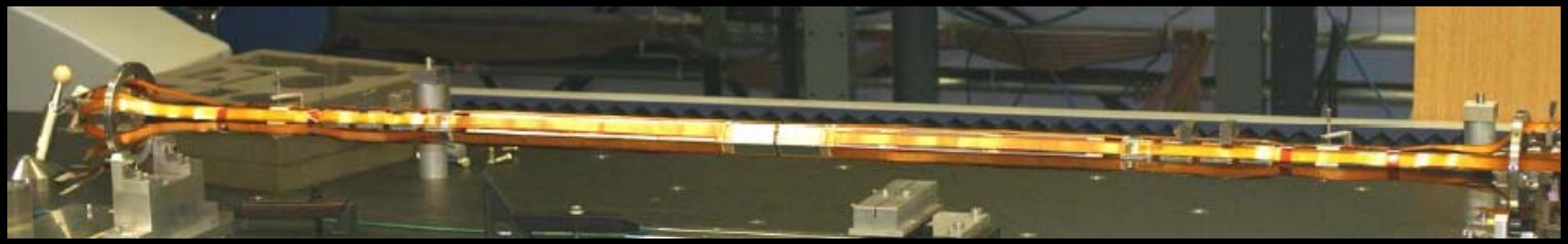
- No pickup noise at all
- Testing includes
  - burn-in
  - gain & noise
  - thermocycling between 20 and -20 °C



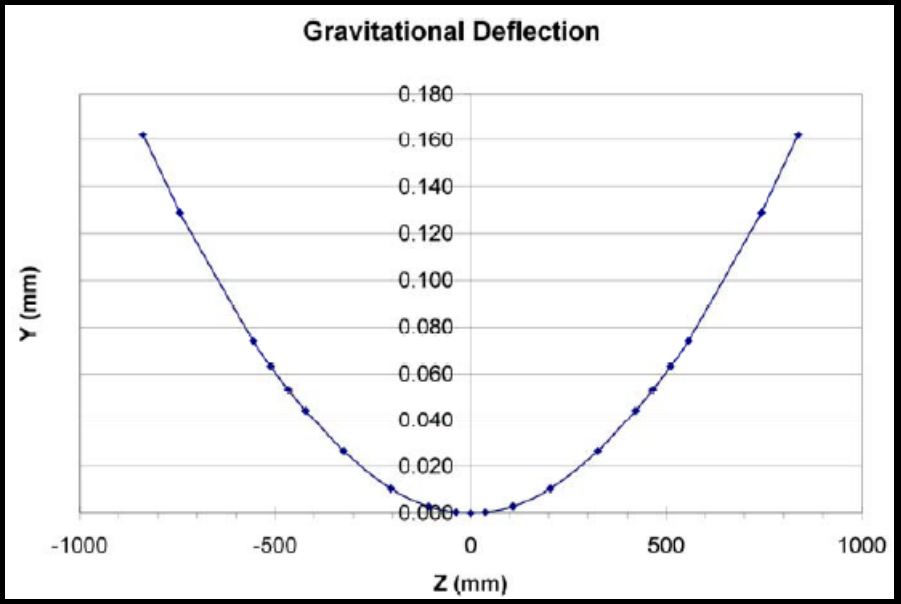


- 75 modules produced
  - < 5 bad channels
  - Current <1.5 μA @ 300V
  - No pinholes
  - Have 1 good spare for each type

Assembly



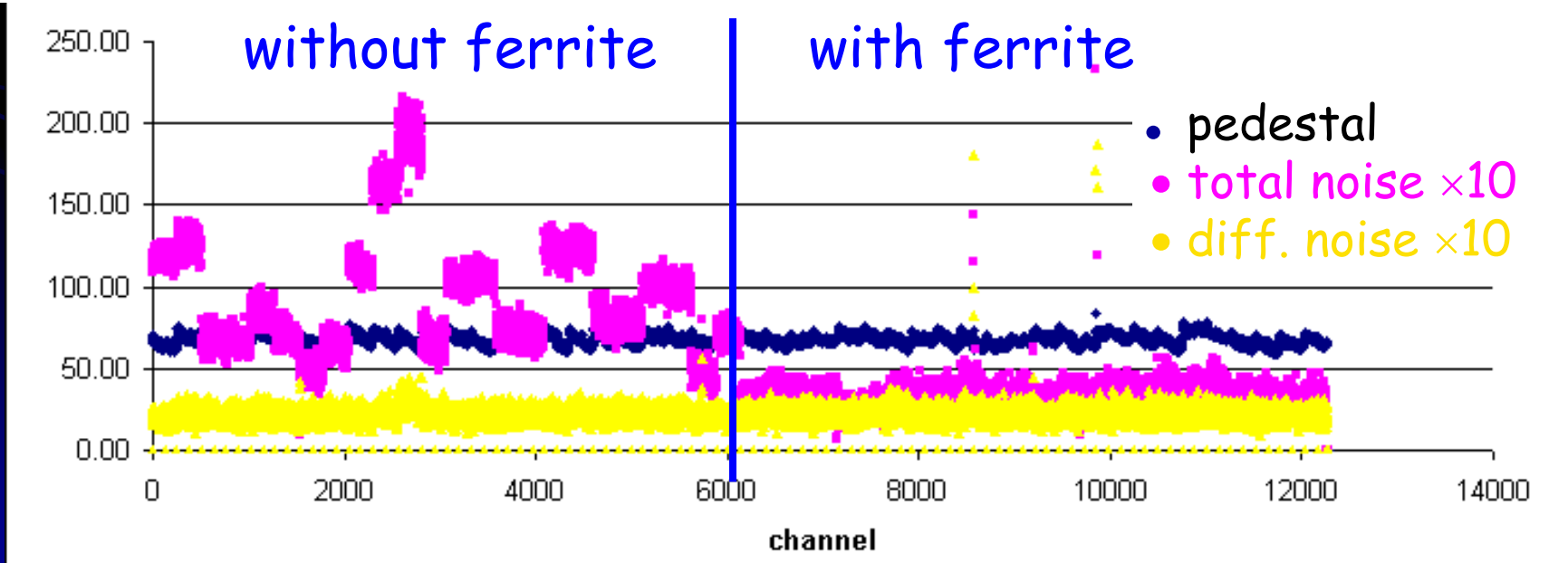
- Module assembly and installation to support structure completed in August 1st
  - deflection ~0.027 mm over the sensor region
  - installation alignment 2-3 μm
  - **all chips are working**
  - **outer radius measured and cofirmed to fit in**



Noise

- Layer 0 ground has to be isolated to avoid possible grounding loop (no external pickup in common ground scheme)
  - increase sensitivity to external pickup → requires filtering for SVX4 power lines → S/N~16

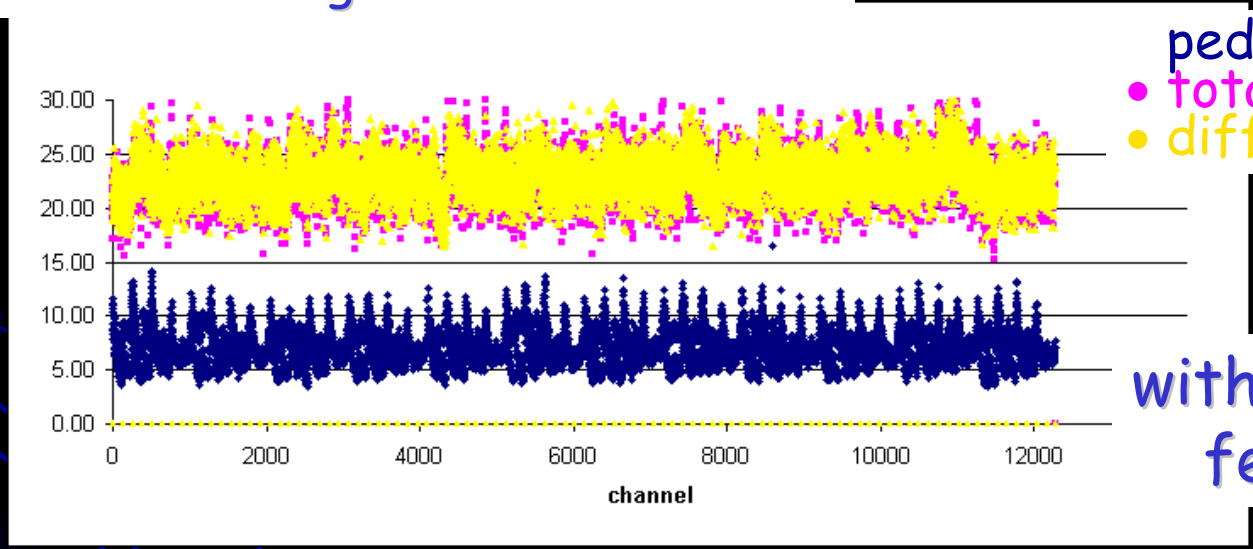
fast bandwidth settings to enhance noise



Final Weapon – RTPS

- Big redundancy
  - as long as coherent, external pickup can be suppressed by real time pedestal subtraction (RTPS)

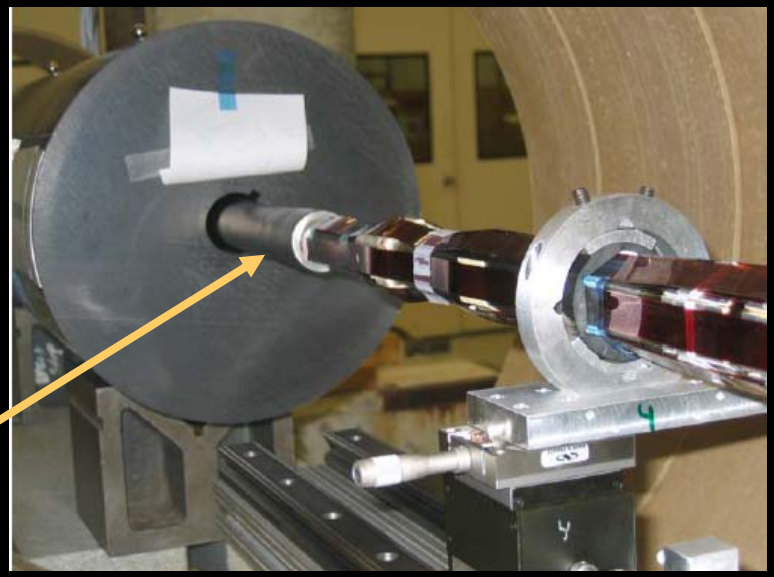
fast bandwidth settings to enhance noise



  - With either RTPS or filtering of power lines, S/N can be ~16 at the nominal bandwidth setting

Installation

Multiple successful test insertions of a prototype in a mock-up of the DØ detector



Installation tool grabs Layer 0 prototype

Conclusions

- Layer 0 detector built to achieve better impact parameter resolution
- R&D and people for Run 2b were fully utilized
  - rad-hard sensor
  - analog cable technology
  - advantage of using SVX4 over SVX2
- Very tight clearance
  - cleared severe mechanical constraints
  - developed installation procedure
- Establish low noise system although its challenging design: S/N~16

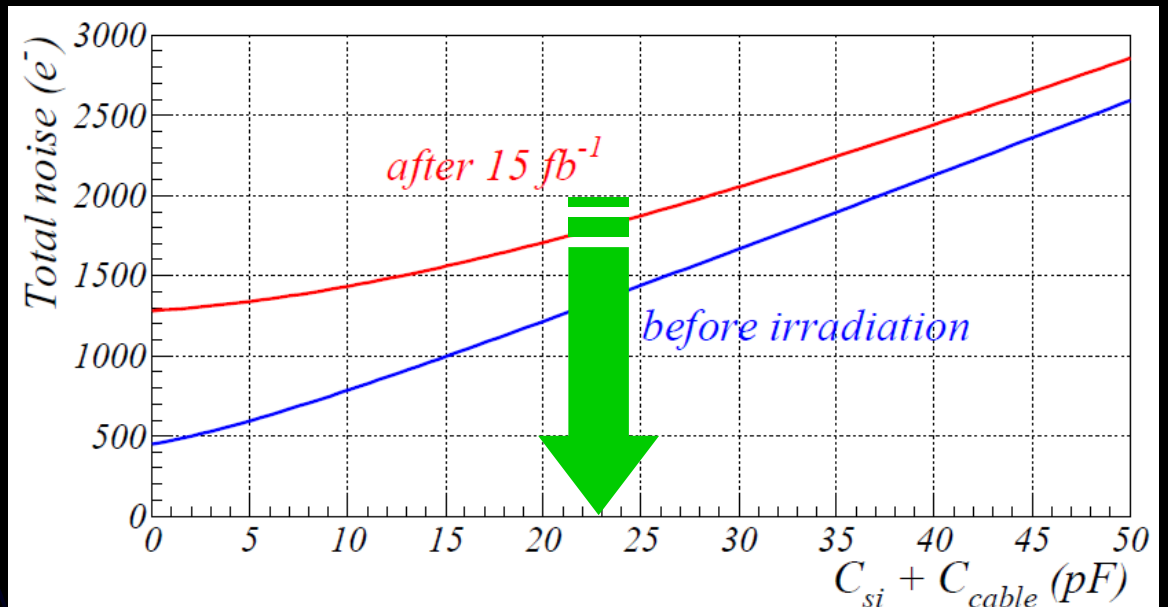
Backup

Analog Cable

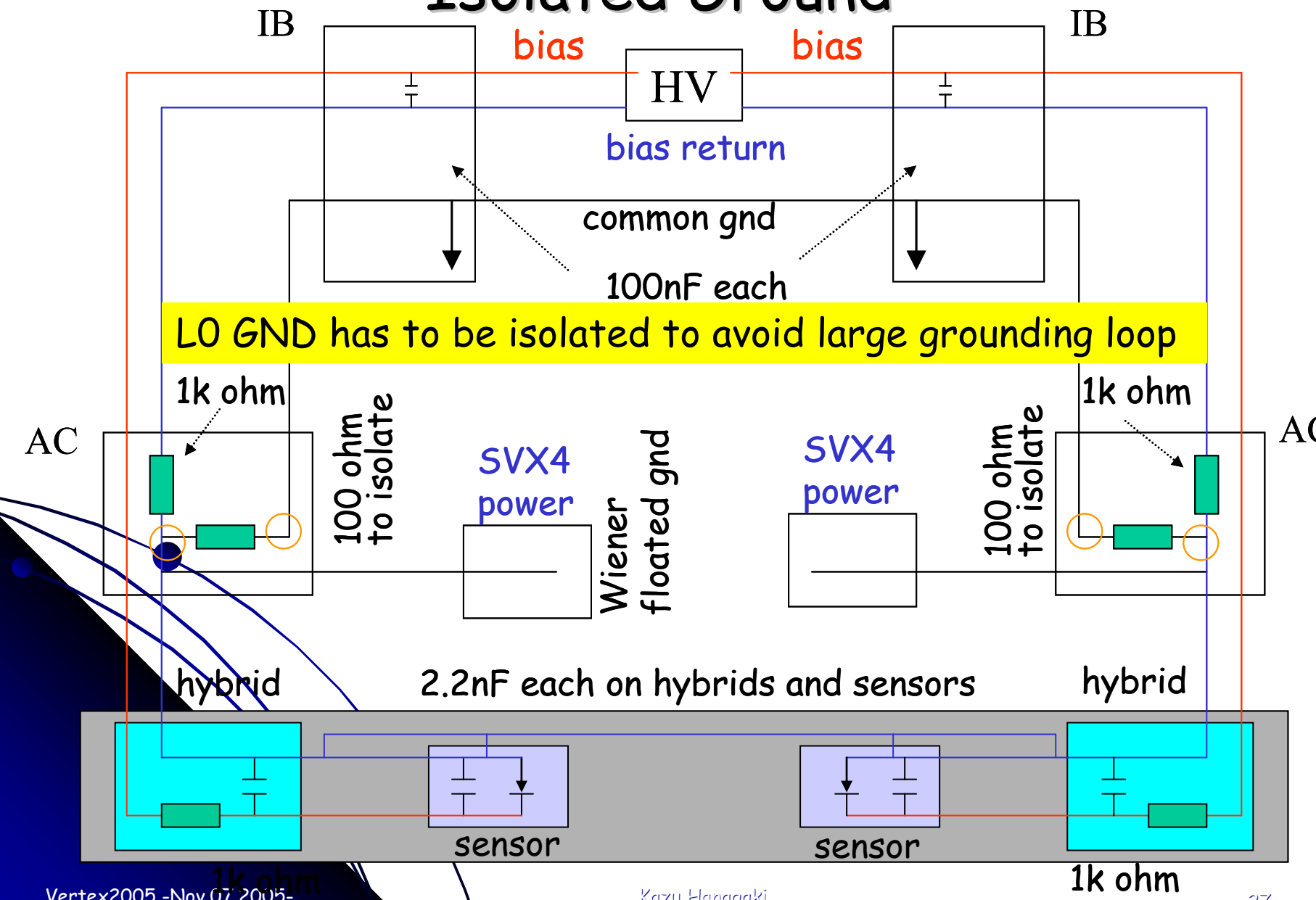
- Flex circuit fabricated by Dyconex (Switzerland): fine pitch (91μm) copper traces on Kapton substrate
- Length 20, 27, 34, 36 cm
- Small capacitance (0.4pF/cm) to reduce noise

S/N can be well above 10

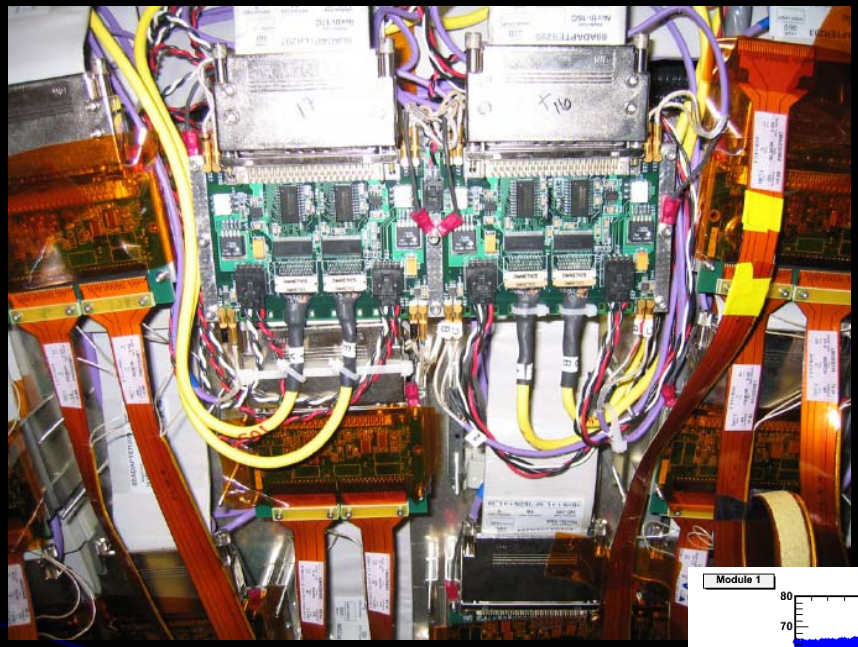
23000 e / MIP



Isolated Ground



Readout in the Real System



- Two modules and two hybrids installed in DØ
  - testing of readout with full DAQ system

- SVX2 and SVX4 have different control sequence, power, data format → train both online and offline software